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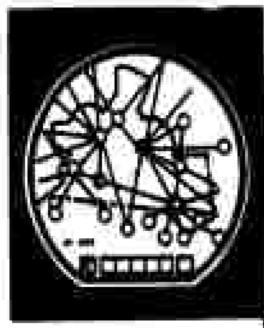

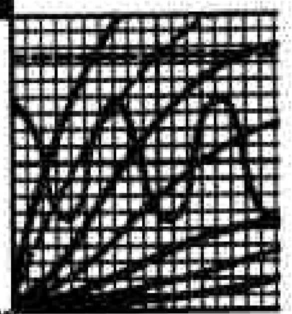

FINAL REPORT

Project No. 432-1-5V

EVALUATION OF LIGHTED CROSSBARS AND LIGHTED RUNWAY DISTANCE MARKERS

FEBRUARY 1964

FEDERAL AVIATION AGENCY

Systems Research & Development Service

EVALUATION DIVISION

Atlantic City, New Jersey

FINAL REPORT

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PROJECT NO. 432-1-5V
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This report is approved for submission to the Director, Systems Research and Development Service. The conclusions and recommendations are those of the Evaluation Division. This report does not necessarily reflect FAA policy in all respects and it does not, in itself, constitute a standard, specification or regulation.

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February 1964

FEDERAL AVIATION AGENCY
Systems Research and Development Service
Evaluation Division
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February 1964, 34 pp., incl. 13 illus.
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ABSTRACT

Lighted crossbars extending across the width of the runway spaced at 1000-foot intervals, and internally lighted frangible distance markers adjacent to the runway also spaced at 1000-foot intervals, were evaluated at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, to determine a suitable system for providing runway distance-to-go information during takeoff and landing operations. Painted numerals, of the type developed and used in the United Kingdom, were also appraised. Flight testing was conducted in unlimited and restricted visibility conditions. Portions of the restricted visibility conditions were simulated using the Cockpit Fog Simulator of the Link Division, General Precision, Inc., and fixed density sheets of Mylar film to obtain a runway visual range (RVR) of approximately 1500 feet.

It was determined that crossbars alone did not provide adequate distance-to-go information. Distance markers were not as effective as painted numerals under the lower visibility conditions. Crossbars when added to distance markers did not substantially improve the information obtained. High wind and engine blast effects caused marker damage.

Numerals painted on the runway surface and located near the runway centerline were more effective than lighted runway-distance markers under the lower visibility conditions.

It was recommended that the suitability of a combination of lighted runway-distance markers and numerals painted on the runway surface for providing distance-to-go information for civil aircraft operations be confirmed by an in-service test.

INTRODUCTION

Purpose

The purpose of this project was to evaluate the suitability of lighted crossbars, lighted distance markers, and painted numerals for providing runway distance-to-go information during takeoff and landing operations.

Background Information

A United States Interim National Standard for Runway Distance Markers (AGA-NS-9) was established August 6, 1958, to authorize the installation of distance markers at joint use civil-military airports because of a military service operating requirement for distance-to-go information.

Interest in runway distance markers has been increasing in the United States and other States of the International Civil Aviation Organization since an indication of position along the runway during takeoff and landing is considered highly desirable, if not essential, in low visibility operations. The requirement for distance information has become more evident since the introduction of jet aircraft into civil air carrier operations.

Proposals have been made in previous years for electronic/electromechanical systems which were intended to provide distance information in the cockpit; however, these systems have not proven successful. It was believed such a system would be more effective, especially during low visibilities, than one depending on pilot vision directed outside the cockpit. Lacking a suitable in-cockpit aid, visual aids were developed to provide distance information.

The project to evaluate distance marking systems at NAFEC involved lighted crossbars and lighted distance markers. Numerals, painted on the runway surface in accordance with specifications developed in the United Kingdom, were also included late in the flight test program.

Equipment

Lighted Crossbars: The crossbars utilized two basic types of bidirectional inset lights; an enclosed type manufactured by Westinghouse Electric Corporation and open types manufactured by Sylvania Electric Products Incorporated, Structural Electric Products Corporation and the Stillman Rubber Company. Each fixture was approximately eight inches in diameter and contained a 45W quartz lamp.

The Westinghouse fixture (FIG. 1) projected 3/8 of an inch above the runway surface. The Sylvania (FIG. 2) and the Structural (FIG. 3) fixtures projected 1/4 inch above the surface. The Stillman fixture (FIG. 4) projected 7/16 of an inch above the surface and was so constructed that pressure from above compressed the fixture flush with the runway surface.

Lighted Distance Markers: The lighted runway distance markers manufactured by Aeronautical Incorporated (FIG. 5) were of a triangular shape, six feet high and mounted on a four-foot square base. These markers were assembled from three components: (1) a frangible structure, (2) a removable numeral panel, (3) a base plate with lamps for internal lighting.

The frangible structure was of steam molded Dylite Polystyrene beads, 1/8 inch to 3/16 inch in size. The density of the Dylite material was approximately one pound per cubic foot, the compressive strength was 12-22 psi, and the tensile strength 25-55 psi.

Numeral panels were made of acetate butyrate 0.060 inches thick and approximately three feet wide and five feet high. Each numeral was two feet wide by four feet high, translucent white against an opaque black background. The panel was secured to the frangible basic structure by six plastic nuts and bolts. Each marker contained two numeral panels, mounted back to back, to permit viewing from either side.

The base plate and the base plate collar were made of heavy fiberglass material. Four lamps were mounted within the base plate in adjustable lamp holders to permit individual aiming of the lamps for maximum illumination of the numerals (FIG. 6).

Painted Numerals: Two numerals, 7 and 8, of a style used in the United Kingdom were painted on Runway 13 for comparative tests with the distance markers (FIG. 7). Both numerals were 100 feet long. The average width of number 7 was 6 feet, the average width of number 8 was 5 feet, and the average stroke width of each number was 15 inches. A black border outlined each number and extended the painted surface to a length of 125 feet. The number 7 border width measured 5 feet at the base and 12 feet at the top. The number 8 border width measured 8 feet at the base and 9 feet at the top.

Installation

General: All aids were installed to serve Runway 13, the precision instrument runway at NAFEC. Figure 8 shows the installation of the crossbars and distance markers in detail, including variations in distance

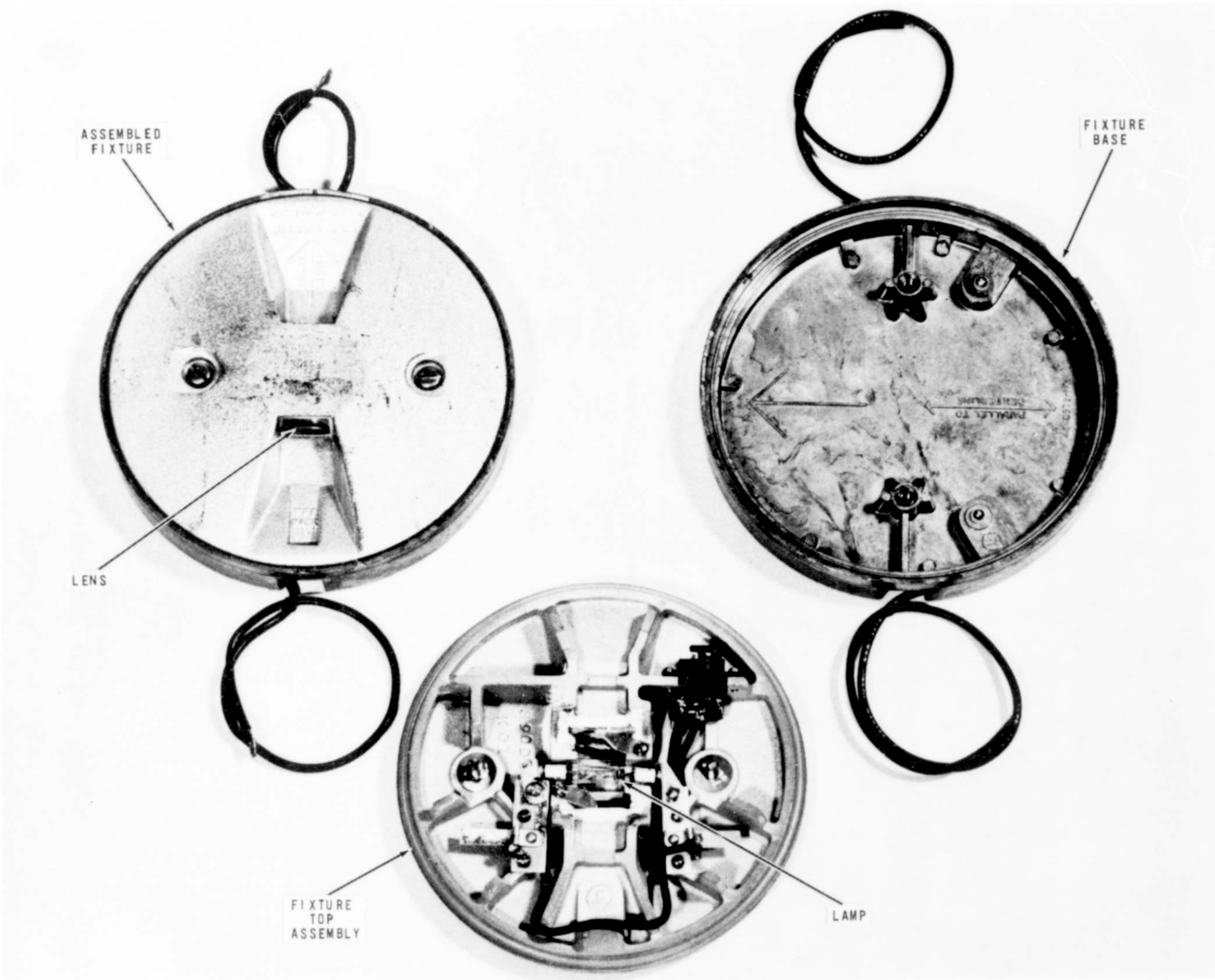

FIG. 1 WESTINGHOUSE ELECTRIC CORPORATION FIXTURE

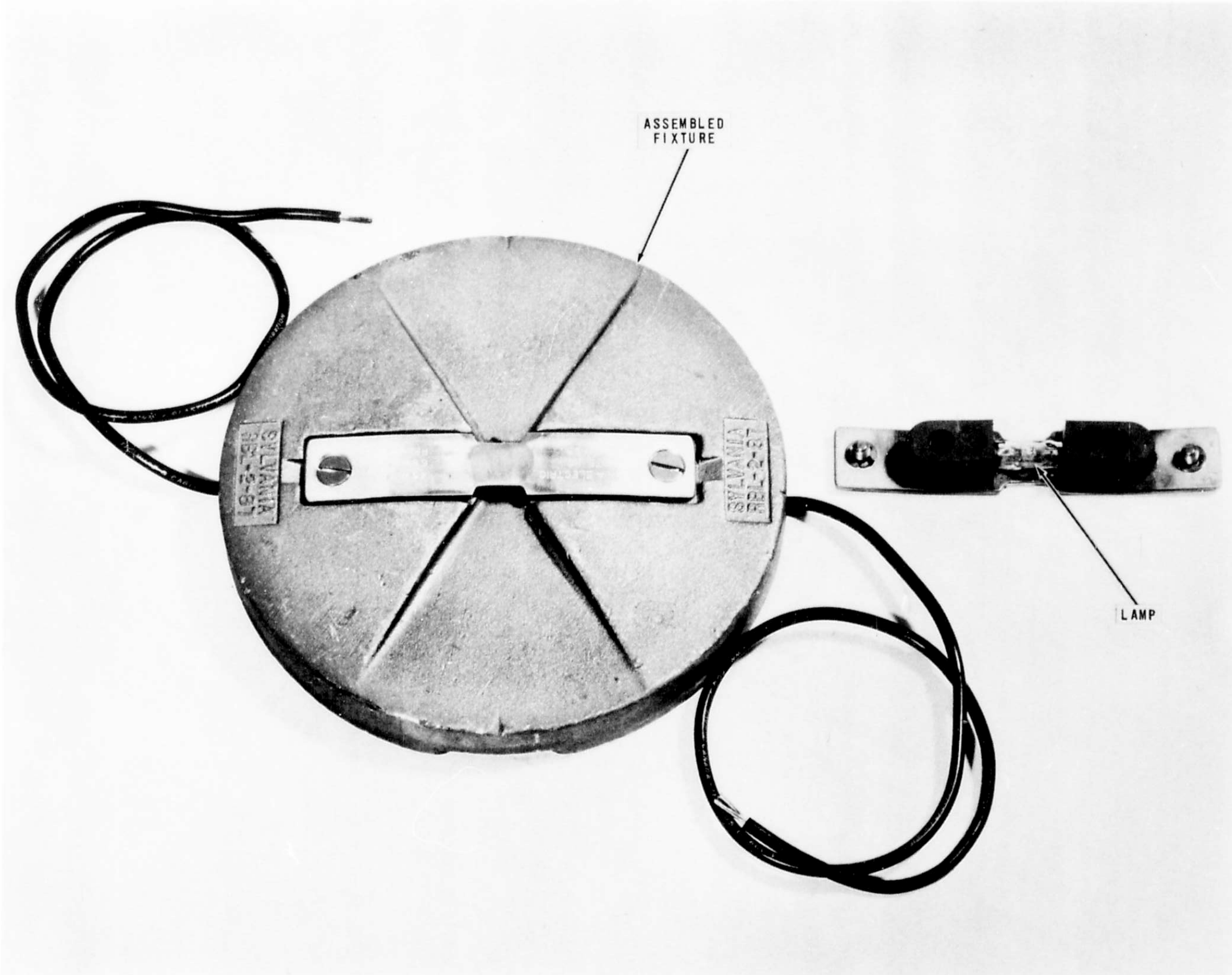

FIG. 2 SYLVANIA ELECTRIC PRODUCTS INCORPORATED FIXTURE

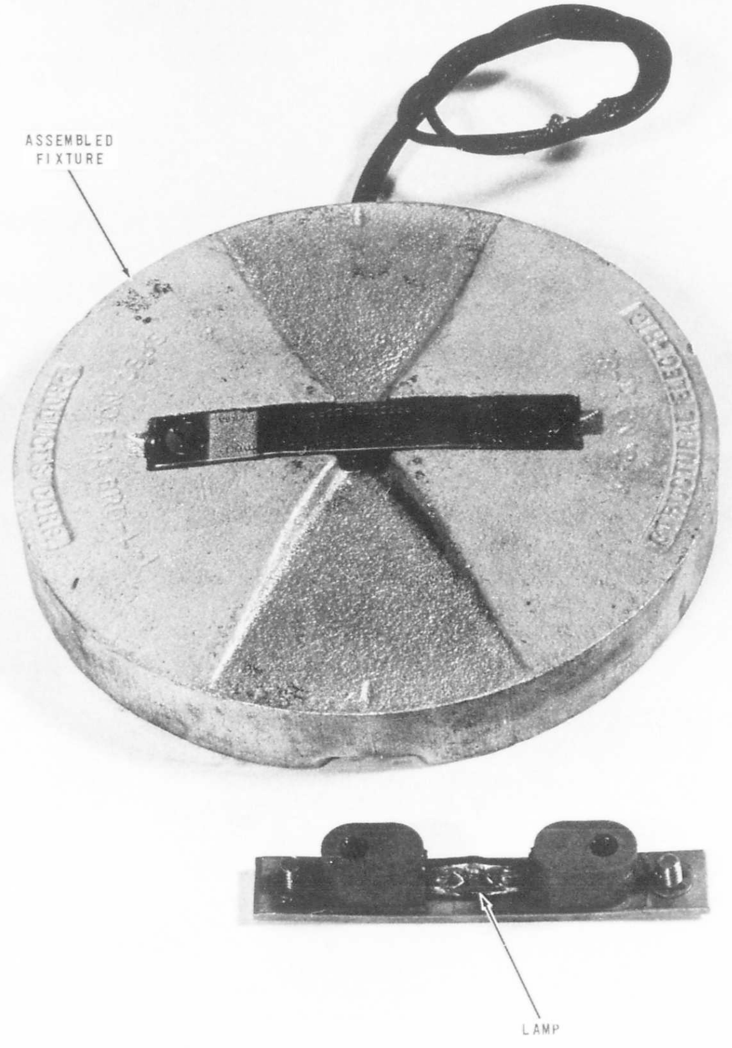

FIG. 3 STRUCTURAL ELECTRIC PRODUCTS CORPORATION FIXTURE

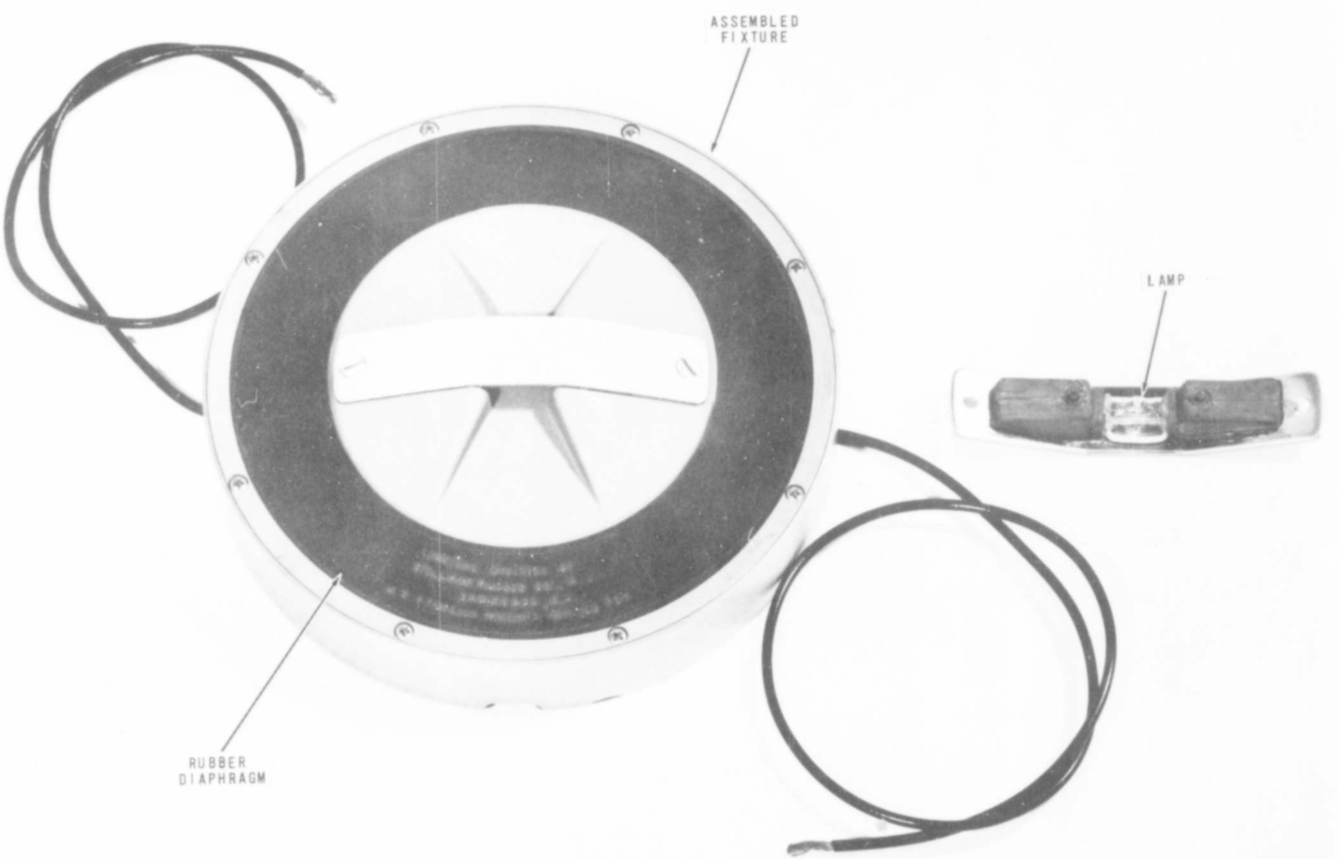

FIG. 4 STILLMAN RUBBER COMPANY FIXTURE

FIG. 5 RUNWAY DISTANCE MARKER

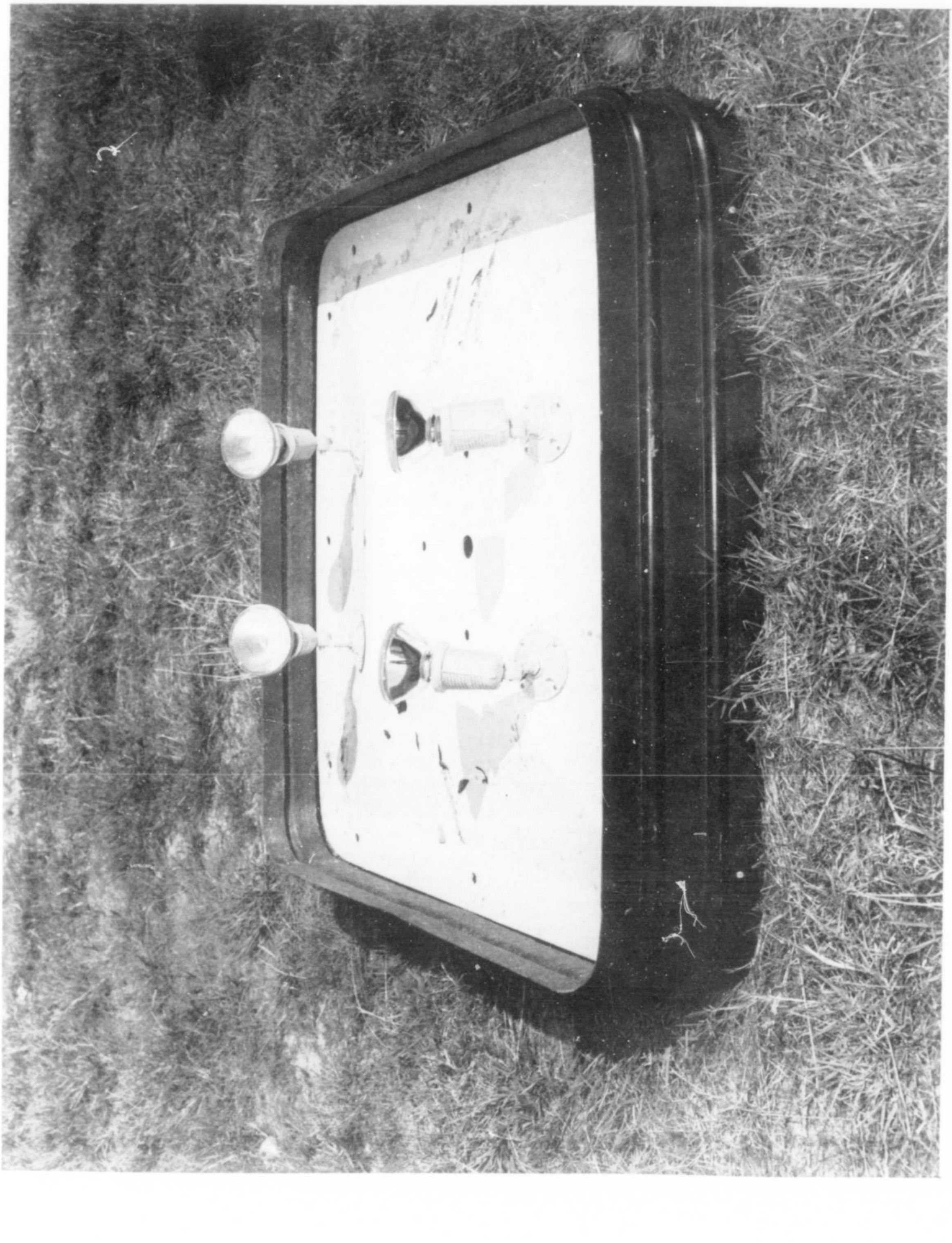

FIG. 6 MARKER BASE PLATE AND COLLAR WITH ELECTRICAL ASSEMBLIES FOR INTERNAL LIGHTING

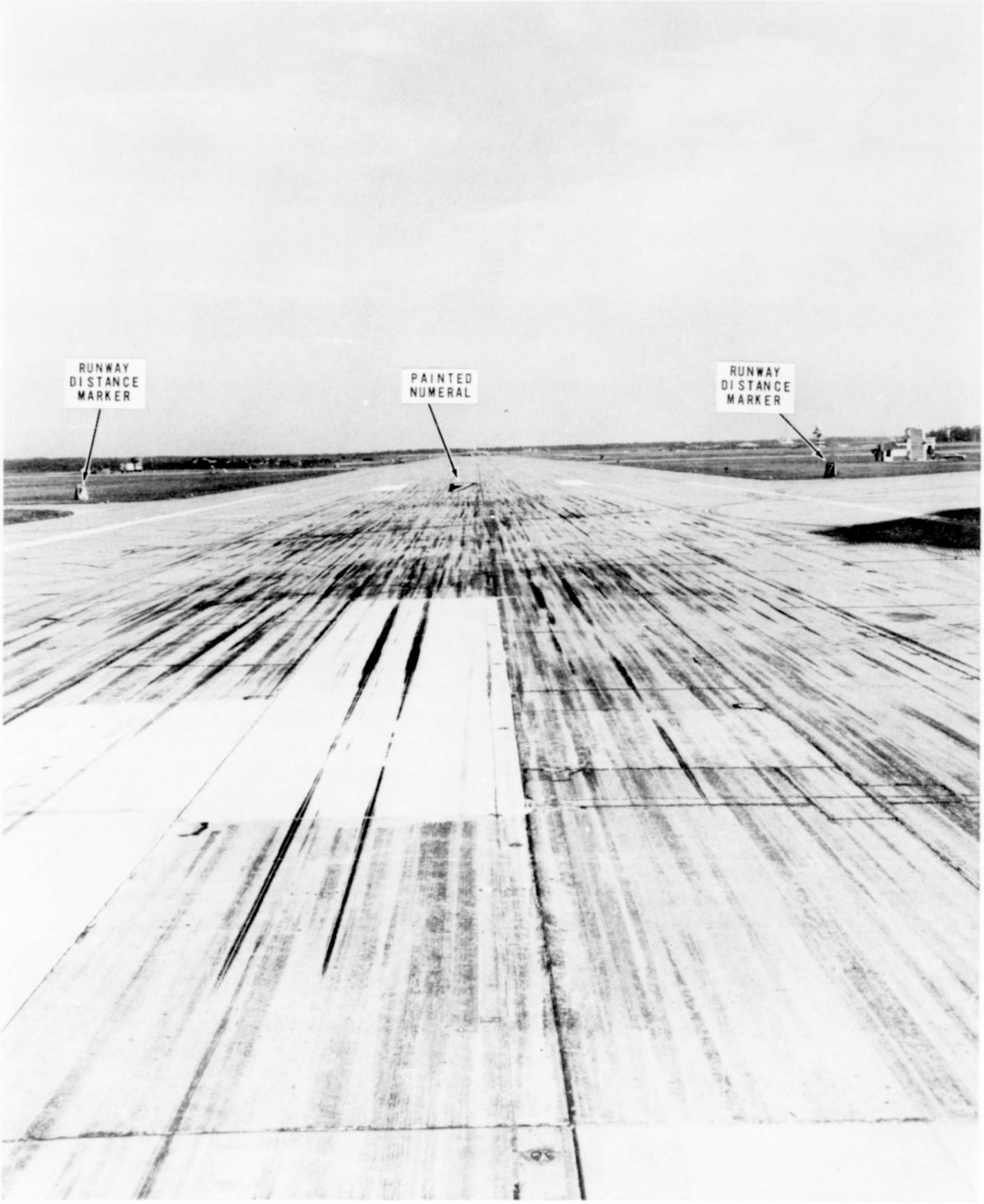

FIG. 7 PAINTED RUNWAY NUMERAL AND MARKERS VIEWED FROM COCKPIT HEIGHT AT A DISTANCE OF 500 FEET

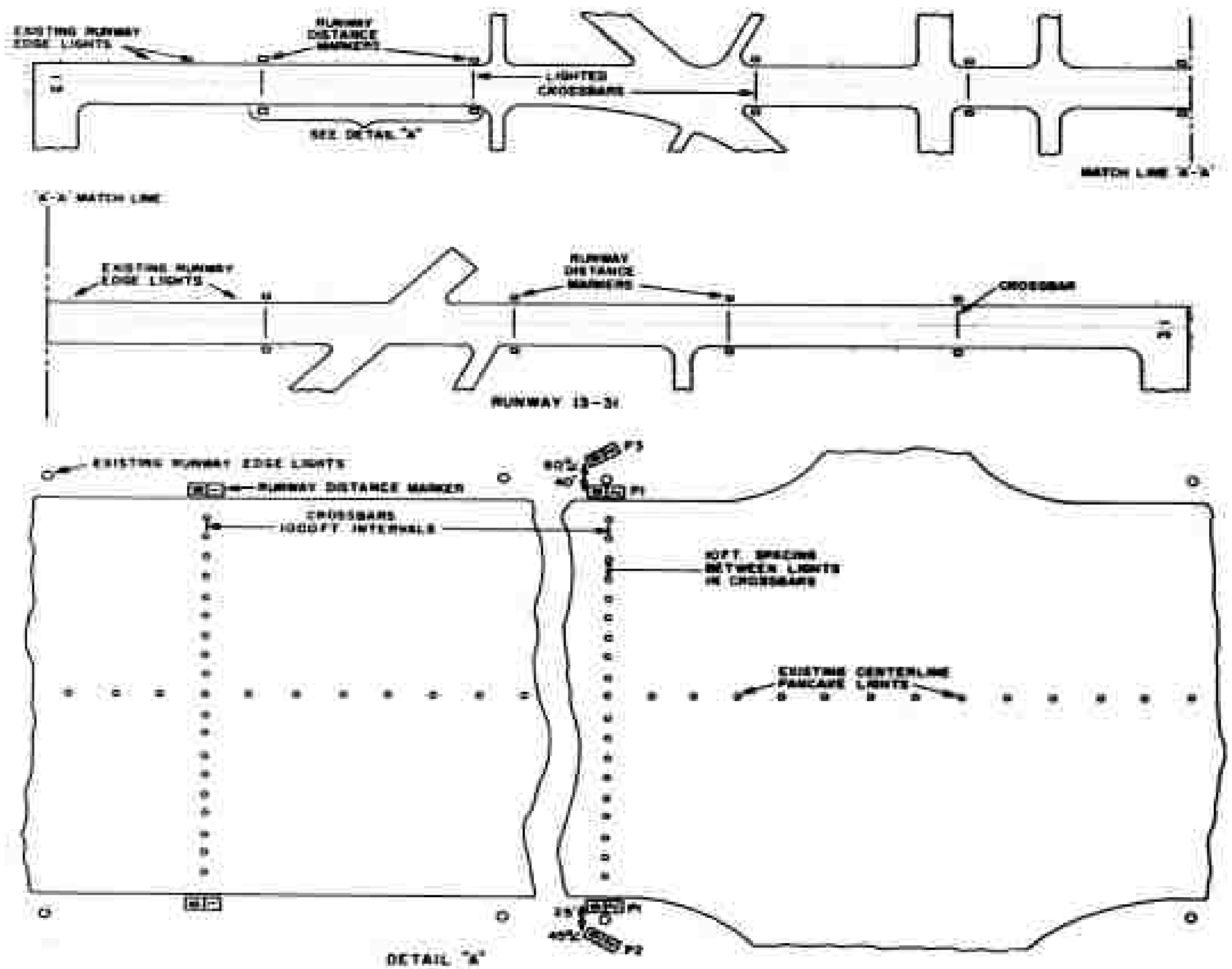

FIG. 8 EQUIPMENT LAYOUT OF CROSSBARS AND DISTANCE MARKERS RUNWAY 13-31

marker location and orientation. The crossbars and markers were installed at approximately 1000-foot intervals along the runway originating 1000 feet from the end of the runway. Runway centerline lighting and edge lighting were used with all test configurations. Intersecting runways and taxiways interfered with optimum location of some of the markers, but it was possible to hold variations to less than 100 feet in such cases so that distances could be considered as nominally 1000 feet increments.

Lighted Crossbars: Inset lighting fixtures were used to form crossbars intersecting the runway centerline at right angles. Nine crossbars, each containing nineteen fixtures on 10-foot centers, were installed at intervals of 1000 feet along the runway with each crossbar spanning the full width of the runway.

The electrical installation consisted of a 2300V single phase, two wire primary circuit, fed through a 7.5KV oil switch to a 25KVA single phase transformer. The 230V, secondary was connected to the primary side of a 15KW, step type, 6.6A constant current regulator.

Power to the 45W, 6.6A fixtures was supplied through direct burial 6.6A to 6.6A series isolating transformers. Each crossbar had two series circuits of five lights each, and two series circuits of four lights each. The runway centerline light was included in each crossbar pattern. A five-position switch permitted selection of the desired light intensity.

Lighted Runway-Distance Markers: Lighted runway-distance markers were installed on each side of the runway adjacent to the crossbars at 1000-foot intervals. The markers indicated, by a single digit display, the length of runway remaining (distance-to-go) in thousands of feet.

Isolating transformers were connected in series with the runway edge lighting circuit to provide the electrical power for the four PAR-38, 60W floodlights in the base of each marker. The common circuit for runway edge lighting and distance markers provided a means by which the illumination of the markers could be varied through five intensity steps.

Different locations and orientations for the distance markers were evaluated. These are shown as P1, P2, P3 in Figure 8 and are explained as follows:

P1 Original location of markers adjacent to the crossbars and 5 feet from the runway edge. The face of each number was perpendicular to the runway centerline.

P2 The markers on the south side of the runway were repositioned 25 feet from the runway edge. The face of each number was rotated to an angle of 45 degrees with the runway centerline. Markers on the north side of the runway were left in the P1 position. With this orientation, bidirectional usage was possible with the markers only on the north side of the runway.

P3 Markers on the north side of the runway were repositioned 40 feet from the runway edge. The face of each number was rotated to an angle of 60 degrees with the runway centerline. Markers on the south side of the runway were left in the P2 position. This orientation permitted usage of the markers only when operating on Runway 13.

Painted Numerals: The number 7 was located on the runway in line with the distance markers indicating 7000 feet of runway remaining when landing on Runway 13. The number 8 was located 1000 feet from the number 7 at the next 1000 foot position toward the end of Runway 13. Both numerals were centered at a distance of 6 feet to the left of runway centerline. The numerals were applied with white traffic paint and reflective beads were sprinkled on the surface. Black lacquer was used in the border outlining the numerals.

A complete system of painted numerals would require another number on the right side of the runway centerline oriented to be read by pilots operating aircraft in the reverse direction.

DISCUSSION

Test Program

Flight Tests: Three patterns, intended to provide distance-to-go information and designated as A, B, and C, were established for comparative testing.

Pattern A (FIG. 9) consisted of the crossbars plus runway edge and centerline lighting.

Pattern B (FIG. 10) consisted of the distance markers plus runway edge and centerline lighting.

Pattern C (FIG. 11) consisted of a combination of crossbars and distance markers plus the runway edge and centerline lighting.

Toward the end of the project a brief check was made to compare lighted runway-distance markers with painted numerals.

Project flying was accomplished in two phases:

Phase I - All project flights in Phase I were conducted on Pattern A in VFR weather. Twelve subject pilots participated in this phase, making touch-and-go and full-stop landings with five types of aircraft: the C-54, G-159, C-131, C-45, and C-135A. A total of thirty-eight operations were conducted, twenty-six of which were touch-and-go and twelve of which were takeoff and full-stop.

Phase II - Flight tests during Phase II were conducted on Patterns B and C in VFR and simulated IFR conditions. The latter was accomplished by the use of the Link Cockpit Fog Simulator installed in the C-54 and fixed sheets of Mylar mounted in panels and secured behind the windshield of the C-131 aircraft. Twelve subject pilots participated in this phase, making touch-and-go and full-stop landings with four types of aircraft: the F9F, C-54, C-135B, and C-131. A total of one hundred and eighteen operations were conducted, eighty-six of which were touch-and-go and thirty-two of which were takeoff and full-stop.

In addition to the Phase I and Phase II tests, a check was made on the painted numerals using C-131 and Aero Commander aircraft in VFR daylight operations and a DC-7 in actual weather when the runway visual range was 1000 feet during daylight hours.

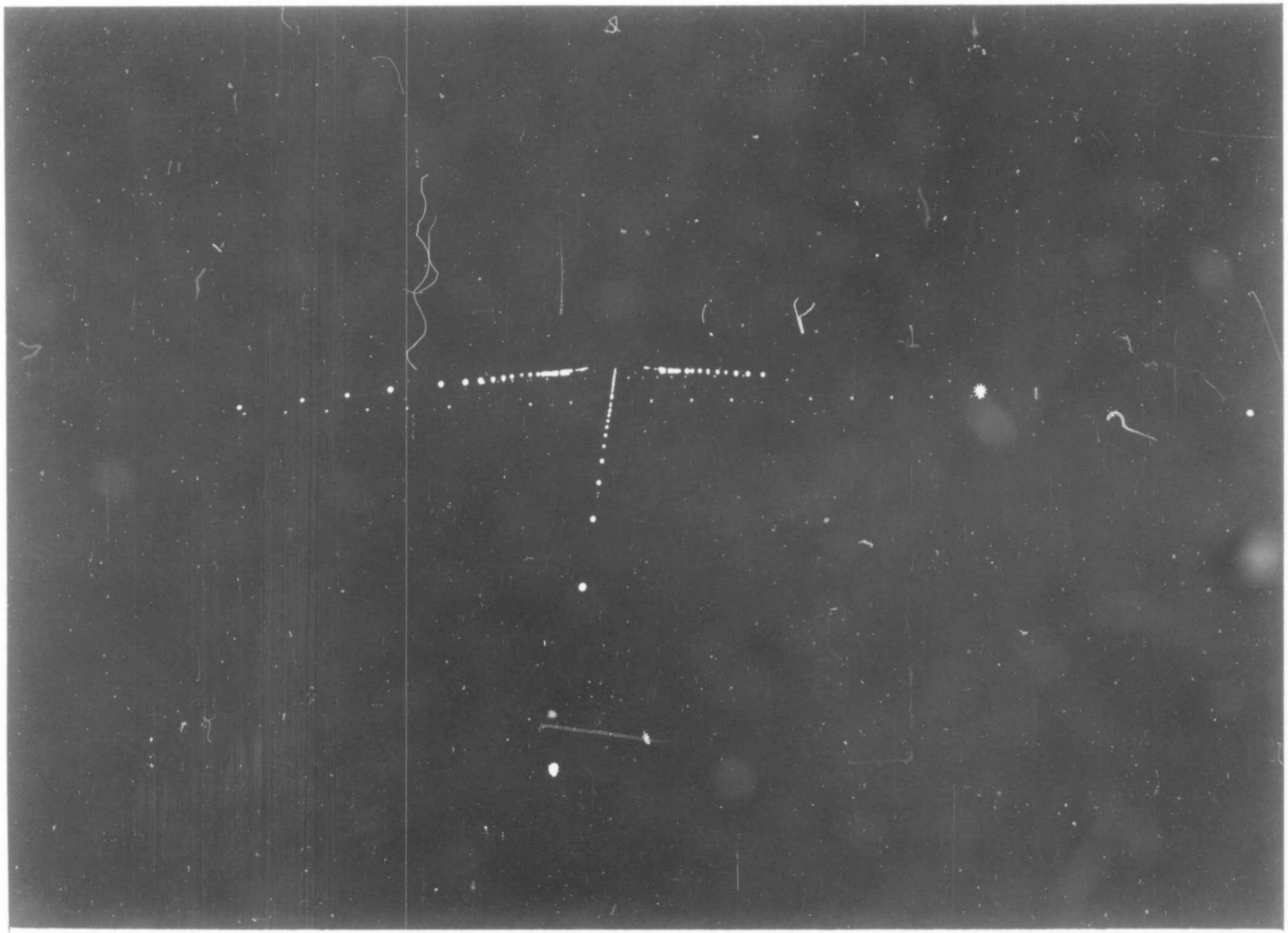

FIG. 9 PATTERN "A" - CROSSBARS WITH RUNWAY EDGE AND CENTERLINE LIGHTING

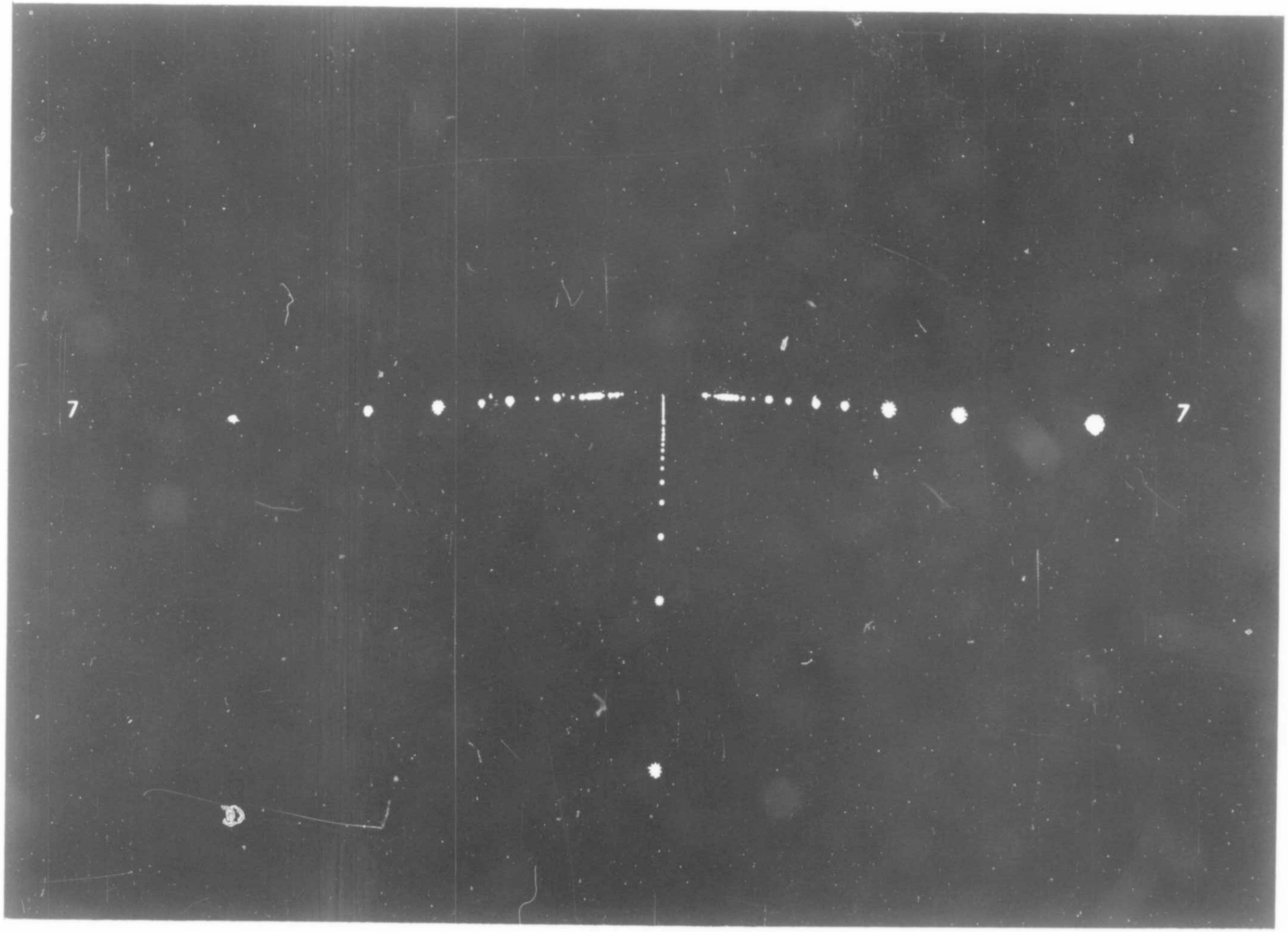

FIG. 10 PATTERN "B" - DISTANCE MARKERS WITH RUNWAY EDGE AND CENTERLINE LIGHTING

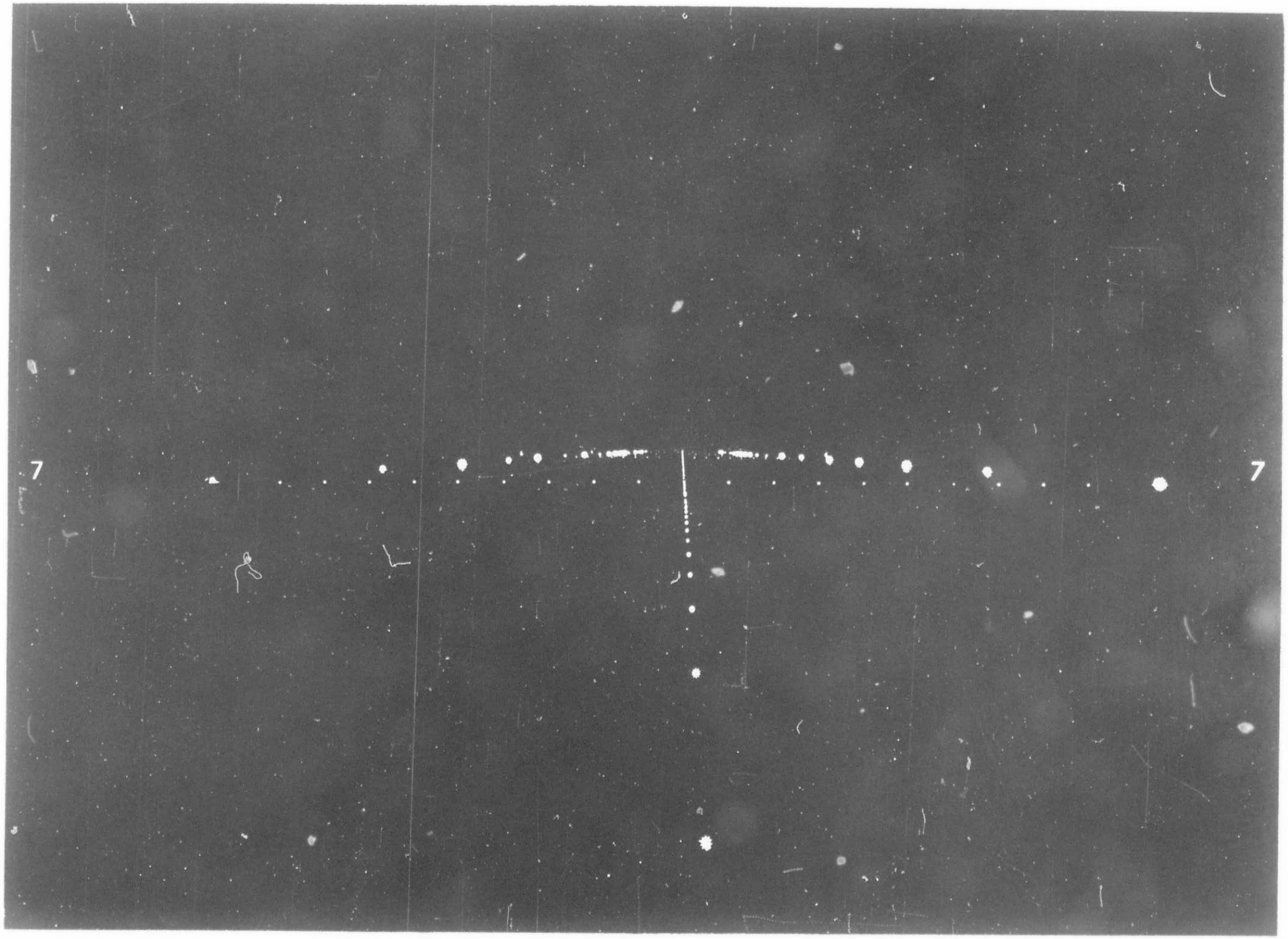

FIG. 11 PATTERN "C" - DISTANCE MARKERS AND CROSSBARS INCLUDING RUNWAY EDGE AND CENTERLINE LIGHTING

Four pilots of the Military Air Transport Service (MATS), 1611th Air Transport Wing, McGuire Air Force Base, New Jersey, flying C-135 aircraft augmented eighteen FAA pilots.

The pilots were instructed to use the visual aids for determining distance traveled during takeoff and for determining distance-to-go during landing. As the aircraft progressed through takeoff, landing or rollout, a cockpit observer challenged the pilot by calling "distance" at any position on the runway. Pilots responded by announcing distance traveled or remaining in thousands of feet when abeam the next distance marker or upon traversing the next lighted crossbar. The challenges were presented at various random distances from the crossbars and distance markers, allowing the pilot a varying interval for recognition and interpretation of distance information.

An effort was made to maintain controlled visibility conditions during Phase II, using the Link Division Airborne Fog Simulator (FIG. 12) and fixed sheets of Mylar film. The Fog Simulator and the Mylar film were developed to simulate day and night fog conditions during landing and takeoff maneuvers. Each visibility range was simulated by an 8-inch wide Mylar film sprayed with clear lacquer to obtain fog impressions (similar to a steamed-up windshield in a car).[1] A runway visual range of 1500 feet was simulated during the flight test program.

Pilot observations and comments concerning the accuracy of the simulation procedure indicated that they felt the use of Mylar film resulted in reasonably accurate RVR simulated conditions. However, they also noted the following discrepancies between the simulated and actual fog conditions:

1. White lights viewed through the Mylar film tended to appear reddish-orange.

2. An intense halo of diffused light surrounded the light source, especially when viewed at close ranges.

<u>Frangibility Tests</u>: A C-135A aircraft was used to determine the ability of the markers to withstand jet blasts. Engine runup was made with the tailpipe of number four engine directed toward a marker. This test was conducted because it is not unusual for air traffic control to clear aircraft for 180 degree turns on runways.

1. Final Report "Airborne Fog Simulator," Link Division, General Precision Inc., FAA/BRD-416, May 1962.

FIG. 12 LINK DIVISION FOG SIMULATOR INSTALLED IN C-54G COCKPIT

Tests were performed by the Experimentation Division at NAFEC to determine if light aircraft would be damaged when colliding with the markers.[2] A light fabric-covered aircraft, no longer airworthy, purposely made collisions while taxiing. The collisions were controlled so as to produce a series of wing and propeller impacts with varying power settings and aircraft speeds.

Ingestion Test: A test to investigate the effects on engine performance resulting from ingestion of Dylite material was conducted by the Experimentation Division.[3] A Pratt and Whitney J-57-P-37 turbojet engine was utilized. The engine was mounted in a static test stand with a Pratt and Whitney bell mouth and standard exhaust nozzle installation. This test involved the release of 5.3 ounces of Dylite from a chute mounted on the engine bell mouth at the twelve o'clock position. The size and shape of the Dylite was of random nature. All parameters needed to compute engine performance were recorded, the engine was inspected, and high speed motion pictures were taken for data collection purposes.

Environmental Tests: Ground observers viewed the lighted markers through Mylar film sheets held across their field of vision. The observers walked along the runway centerline toward the markers until the marker numerals could be seen and accurately interpreted. This distance was then recorded as the recognition distance of the marker. Light intensity and marker position were varied to provide a table of ranges reflecting the effect of these two variables.

2. Final Memorandum Report "Installing and Testing Lighted Crossbars and Runway Distance Markers." FAA/SRDS, Experimentation Division, February 1963.

3. Memorandum Report, "Ingestion of Frangible Runway Distance-To-Go Markers by a Turbojet Engine," FAA/SRDS, Experimentation Division, October 1962.

In addition, the candlepower output of the markers for each intensity step was obtained by photometric means for comparison with corresponding runway edge light values. Records were maintained on physical damage, to include probable or known causes, sustained by components of each system.

Test Results

Flight Tests: Pilot performance was rated by comparing the number of times the pilot failed to identify his position to the number of operations performed. A miss was defined as a position error of 1000 feet or more. Misses were counted even if the subject pilot later re-estimated correctly the position of the aircraft.

Phase I - With Pattern A, the lighted crossbars offered the only means of position identification. This pattern made it necessary for the pilot to note each crossbar in passing and mentally subtract the rows from the total runway length or use a countdown technique to determine the distance-to-go. In checking takeoff performance, pilots simply counted the crossbars to determine the distance traveled. In this pattern a mistake in counting could not be corrected.

In a total of 38 operations, eleven misses were recorded representing a 29 percent "error factor." Since these results were all obtained in good visibility conditions, further testing in reduced visibility was considered unnecessary.

Phase II: Results obtained in early flight tests with the Link Fog Simulator showed that the marker installation adjacent to the runway (Position P1) resulted in a high percentage of misses for both Pattern B and Pattern C. As it was apparent that the problem was due to interference with the higher intensity runway edge lights, the markers were located outward to the P2 and P3 positions (as described previously) and the test program was resumed.

Pilot performance on the relocated markers was improved over the original P1 position. The percentage of misses for the P1 position was 50% for Pattern B and 62% for Pattern C in the simulated IFR condition. The percentage of misses for the P2 position was 11% for both Patterns B and C in the simulated IFR condition. The percentage of misses for the P3 position was 18% for Pattern B and 0% for Pattern C in the simulated IFR condition.

The only miss encountered during Phase II in VFR weather conditions for all three marker positions involved the C-135A. A pilot of the C-135 missed 14% for the P2 position, Pattern C.

Table I shows an analysis of pilot questionnaire responses by application of the Binomial Test.* The general picture resulting from the questionnaire responses was that, although the crossbars were observed and seemed to enhance the distance markers, the markers were effective in providing distance-to-go and acceleration information with or without crossbars.

TABLE I

BINOMIAL ANALYSIS OF QUESTIONNAIRE RESPONSES

Phase I Questionnaire	YES	NO	Significant at 0.1 Level
1. Were the crossbar lights observed?	12	0	Yes
2. Were the crossbars alone helpful in:			
a. providing distance-to-go information	2	10	Yes
b. checking acceleration during takeoff	3	9	Yes
3. Were the crossbars a desirable addition to runway lighting?	7	5	No
Phase II Questionnaire			
1. Did the combination of distance markers and crossbars aid in?			
a. providing distance-to-go information	11	1	Yes
b. checking acceleration during takeoff	9	3	Yes
2. Were the distance markers alone helpful in:			
a. providing distance-to-go information	11	1	Yes
b. checking acceleration during takeoff	9	3	Yes
3. Which pattern was more effective in providing distance-to-go and acceleration information?			
a. crossbars and distance markers	8		No
b. distance markers only	4		

*Sidney Siegel, "Non-parametric Statistics," McGraw Hill Book Company, Inc., New York, 1956.

TABLE I (Continued)

BINOMIAL ANALYSIS OF QUESTIONNAIRE RESPONSES

Phase II Questionnaire (continued)	YES	NO	Significant at 0.1 level
4. Was the preferred pattern much better than the other pattern?			
a. crossbars and distance markers	5	3	No
b. distance markers only	2	2	No
5. Was the intensity too bright			
a. crossbars	4	8	No
b. distance markers	4	8	No
6. Distance information is considered to be:			
a. of critical significance to flight operations	8	4	No
b. very helpful for flight operations	12	0	Yes
7. Are the markers considering their height, although frangible, of any concern in aircraft operations?	2	10	Yes

Note: The null hypothesis is that the differences occurred due to chance.

The P1 position of the markers proved to be the least desirable location. The high intensity runway edge lighting interfered with the readability of the marker to such an extent that in one flight period a subject was able to identify the numerals on only a few occasions in the simulated visibility environment.

Angular orientation of the markers in the P2 and P3 positions afforded a more continuous source of distance information, as the aircraft progressed along the runway.

Relocation of the markers from the runway edge improved readability at night, but a problem was created in low visibilities. Pilots diverted their attention from the runway to an off-runway location in order to use the markers at close range, since the markers were in the area of side

vision when the pilot was looking along the runway. This diversion was not considered a problem in good visibility conditions, but it is believed that pilots will be more reluctant to use the off-runway aids during take-off and landing in low visibility conditions due to increased attention to alignment of the aircraft with the runway. Operational use of the distance markers would probably be along the following lines.

For weather conditions of:

1. Unlimited visibility to one-half mile visibility. Pilots could obtain distance information from the markers with ease.

2. One-half mile visibility to one-quarter mile visibility. Some pilots would ignore distance-to-go markers even though distance information would prove useful.

3. Below one-quarter mile visibility. The effectiveness of the markers would be so marginal that pilots desiring distance information would in most instances be unable to identify the markers.

A study was made of several major airports served by jet transports relative to the installation problems that would be encountered with the distance markers. It was noticed that distance marker positions would in some instances conflict with other runways and taxiways making it impossible to provide a complete system of distance markers. The problem was especially critical at airports having high speed exits.

The pilots found the distance markers to be more effective than the painted numerals during the flight checks conducted in VFR daylight conditions. However, in actual IFR daylight conditions with a runway visual range of 1000 feet, the painted numerals were observed during landing but the lighted distance markers were not observed at any time due to the fog.

Frangibility Tests: Power settings of the jet engine in the distance marker blast test were increased from a range of 62 percent (idle speed) through 80 percent of maximum rpm. Jet blast data were obtained from the engine manufacturer and the average peak velocities were calculated in the jet wake area. These velocities varied from 60 fps at idle speed through 100 fps at 80 percent of maximum rpm, at a distance of 75 feet (on centerline) from the jet engine. The wind during the test was parallel

to and in the same direction as the jet blast with velocities of 18 knots and gusts of 23 knots. To determine actual velocities the wind velocity was added to the jet blast velocity; thus, the actual velocities were approximately 90 fps to 140 fps.

The Dylite and numeral panel materials proved highly frangible in the tests performed. Marker deterioration was first noticeable at the 73 percent power setting with actual velocities approximating 100 fps. The marker was blown apart, fractured into large and small fragments and strewn for a distance of 390 feet. The only salvageable item was the base plate which was torn from its tiedowns and hurled 125 feet after the marker had disintegrated.

The test conducted with a jet engine, in which a marker was destroyed, indicates results that can be expected with markers of this type and design. Even higher velocities will be obtained with larger type jet engines such as the JT-4A-9, the engine used in the Boeing 707-320 aircraft series. Table II shows the range of velocities that can be anticipated during ground operations with the larger engines of jet aircraft. Jet wake velocities can damage highly frangible markers where jet aircraft make 180 degree turns on runways. Marker design and clearance criteria are critical matters with respect to this problem.

TABLE II

JET WAKE VELOCITIES FOR JT-4A-9 ENGINE

Distance In Feet	Taxi Power	Maneuvering Power
Rear of Outboard Engine Nozzle	Velocities in fps	Velocities in fps
60	216	276
80	180	235
100	156	201
120	135	176
140	120	151

In the light aircraft marker collision test the marker base was the only component that presented a possible hazard. The height of the base plate collar (8-3/4 inches) and rigidity of the collar were sufficient to restrain the aircraft with its small wheel diameter and light weight. Consequently, the aircraft nosed over when the under carriage contacted the base.

Ingestion Test: The following test results were extracted from a memorandum report titled, "Ingestion of Frangible Runway Distance-To-Go Markers by a Turbojet Engine," October 1962, issued by the Experimentation Division at NAFEC.

"1. It is quite evident that both the low pressure compressor and high pressure compressor were in a stall condition for approximately 1.1 seconds.

2. A total of eight cyclic pressure disturbances are discernible.

3. The low pressure compressor rotor speed decreased during the ingestion sequence and subsequently recovered to the pre-ingestion value approximately 3 1/4 seconds following the initial speed decay.

4. The high pressure compressor rotor speed remained constant throughout the ingestion sequence.

5. The exhaust gas total temperature increased during the ingestion sequence and subsequently decreased to the pre-ingestion value approximately 5 1/2 seconds following initial temperature increase.

6. The high speed motion picture film of the engine exhaust recorded a total of eight distinct "torches." This phenomenon (torching) was due to insufficient airflow associated with the pressure losses, which in turn created rich fuel/air mixtures in the engine combustion section. Therefore, complete combustion did not occur prior to the time the fuel/air mixture entered the turbine and exhaust sections. This resulted in excessive temperatures being experienced by the turbine section. Prolonged exposure to these conditions can result in structural failure."

Environmental Tests: Ground observations conducted during daylight and evening hours confirmed a number of problems with the markers. The marker effectiveness was reduced appreciably in the simulated low visibility. The reduction in effectiveness was apparent in all marker positions but more evident in the P1 position. Table III consists of photometric data for the markers and edge lights at the five intensity steps. Step three was generally used in the flight tests since this intensity afforded the most effective numeral recognition range.

TABLE III

COMPARISON OF % OF MAXIMUM BRIGHTNESS FOR EACH INTENSITY STEP AND BRIGHTNESS IN CANDLEPOWER OF THE RUNWAY EDGE LIGHTS AND DISTANCE MARKERS

Step	% of Max Brightness		Candlepower	
	Edge Lights	Markers	Edge Lights	Markers
5	100	100	20,000	110
4	25	54	5,000	60
3	5	36	1,000	40
2	1	23	200	25
1	.2	14	40	15

The style of the numerals employed in the original distance markers presented some recognition problems. Because of the block design, some numerals could not always be distinguished from others. All errors recorded in the flight tests involved the numbers 8, 6, and 9. Newly designed panels were installed because of the recognition problem. These numerals, specification MIL C-180 12A, were more oval in design having less similiarity among numerals than the original set. The stroke width of the number (white translucent material) averaged 6 inches as opposed to the stroke width of 3 1/2 inches used in the block number panels.

Table IV lists the average recognition range of the markers in feet, as viewed by four observers from the centerline of the runway, of the old and new type numerals located in both the P2 and P3 positions. Recognition ranges as shown in Table IV were obtained in a simulated low visibility condition at night.

TABLE IV

AVERAGE RECOGNITION RANGE OF DISTANCE MARKER NUMERALS VIEWED FROM RUNWAY CENTERLINE IN A SIMULATED WEATHER CONDITION

Step	Old Numeral		New Numeral	
	P2	P3	P2	P3
5	320	500	350	400
4	435	500	650	650
3	500	590	590	680
2	520	550	580	600
1	480	510	380	530

White frangible marker structures were also evaluated during the program. No apparent difference was noted in night observations, however, a definite loss in readability was encountered in daylight due to the poor contrast of the white Dylite structure and white numerals. The white numerals were more conspicuous when mounted on the original dark gray Dylite structure.

Both oval and block style numeral plates presented a common problem during daylight. The panels were extremely glossy and reflected sunlight made numeral interpretation difficult during the period when the pilot was in line with the reflected light.

Table V contains a list of the distance markers destroyed or damaged. One marker was damaged and another marker destroyed by a transient jet aircraft while executing a touch and go landing in a moderate crosswind. Both markers were located in the P1 position adjacent to the runway edge. The damaged marker is shown in Figure 13. Scorching of the marker shown in Figure 13 is evidence of the proximity and/or possible contact of the outboard engine with the marker. A marker in the P2 position was destroyed as a Boeing 707 aircraft egressed from the runway into a taxiway as requested by the control facility to expedite traffic. The marker was struck with the forward part of the left inboard engine.

TABLE V

DAMAGE TO DISTANCE MARKERS

SIGN POSITION	EXTENT OF DAMAGE	PROBABLE CAUSE
P-1	one face plate blown out - plate damaged beyond repair	high wind
P-2	entire structure blown off base - damaged beyond repair	high wind
P-3	both numeral plates lost - basic structure undamaged	wind, gusts up to 56 k peak, average 25 k
P-2	entire marker plus base was lifted from position	wind, gusts up to 56 k peak, average 25 k

TABLE V (Continued)

SIGN POSITION	EXTENT OF DAMAGE	PROBABLE CAUSE
P-2	entire structure blown off base - frangible structure split open	transient jet blast
P-1	entire structure blown off base - damaged beyond repair	transient jet blast
P-1	top of marker removed and side split	transient jet blast
P-3	marker cracked open at base - damaged beyond repair	attributed to arresting gear cable contact
P-2	marker structure destroyed - both numeral panels were shattered	jet aircraft executing sharp turn off runway

The painted numerals were well designed, although inclement weather such as snow, sleet, rain, etc., would render them almost useless. Deterioration of the painted surface caused by tires of landing aircraft further reduced their effectiveness. Continued effectiveness of the painted numerals requires efficient periodic maintenance. With the rapid deterioration encountered in the touchdown zone and the high rate of maintenance required in this area, use of painted numerals should be considered only outside the touchdown zone.

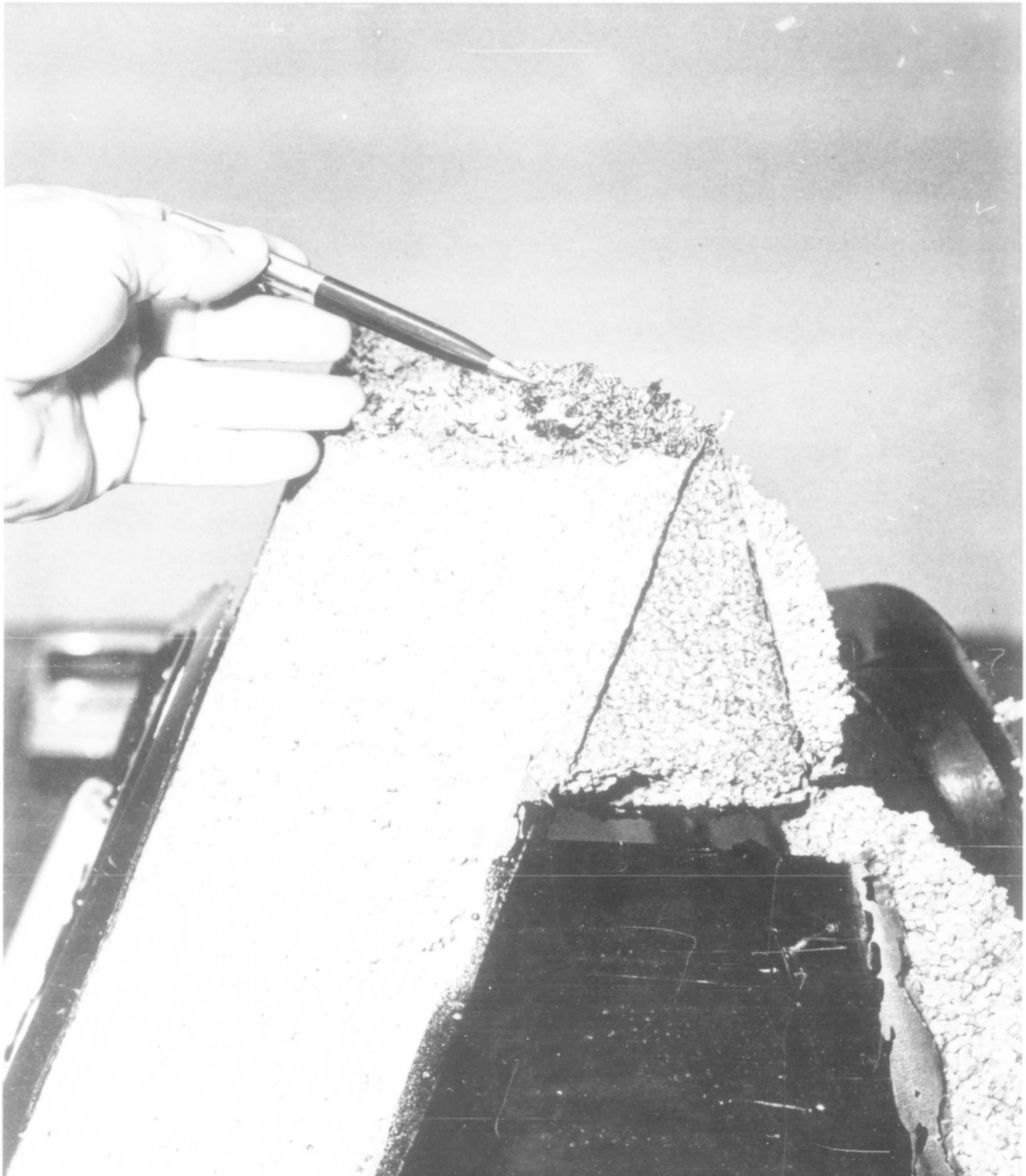

FIG. 13 SCORCHING OF DISTANCE MARKER ATTRIBUTED TO HEAT FROM OUTBOARD JET ENGINE

SUMMARY OF RESULTS

1. Misses in distance identification occurred in 29 percent of the trials using lighted crossbars alone under VFR conditions. Further testing under reduced visibility conditions was thus considered unnecessary.

2. Misses in distance identification occurred in over 50 percent of the trials when distance markers were located at the runway edge during night operations with simulated reduced visibility. There was a substantial reduction in misses with the distance markers positioned 25 to 40 feet from the runway edge.

3. The distance markers were not sighted during day operations under actual weather conditions of 1000 feet RVR.

4. Pilot performance on Pattern B (distance markers only) was essentially the same as pilot performance on Pattern C (distance markers plus crossbars).

5. A 60 degree angular placement of the distance markers with respect to the runway centerline provided optimum display considering both long and short viewing range requirements.

6. The distance markers were sufficiently frangible and did not constitute a hazard to aircraft; however, the markers did not withstand high wind velocities and jet blasts. Locating the distance markers 40 feet from the runway edge, rather than at the edge, minimized marker damage.

7. The dark grey material used in the frangible structure of the distance markers provided greater contrast and numeral readability than the white material.

8. Oval style distance marker numerals with increased stroke width improved the ability to distinguish among numerals.

9. The distance marker numeral plate surface material had a high reflectance factor making the numerals difficult to read in sunlight when the pilot was in line with the reflected sunlight.

10. The painted numerals on dry pavements were effective during day operations under actual weather conditions of 1000 feet RVR.

11. The scuffing effects of aircraft tires during landing obliterated the painted numeral "8" within one month whereas the numeral "7" at 3000 feet from threshold was useful for a period of months.

CONCLUSIONS

Based on the results obtained from the lighted crossbars, lighted runway-distance markers and painted numerals utilized and evaluated as visual aids for providing distance-to-go information during landing and takeoff operations, it is concluded that:

1. Lighted crossbars alone are not adequate.

2. Lighted runway-distance markers are not as effective as painted numerals under reduced visibility conditions and are not effective when located in near proximity to runway edge lights.

3. Painted numerals located near the runway centerline are more effective under reduced visibility conditions than lighted runway-distance markers.

4. Of the visual aids evaluated in this project, a combination of lighted runway-distance markers and painted numerals on the runway surface would more effectively provide distance-to-go information with the markers substituting for the numerals in the touchdown zone of the runway. There is no substantial advantage in adding lighted crossbars to the combination.

5. For all-weather operations, the provision of distance-to-go information by visual aids might be further improved by using lighted numerals or symbols located in the runway in proximity to the runway centerline.

RECOMMENDATIONS

Based on the visual aids that were evaluated, singly and in combination, it is recommended that:

1. The design of the lighted runway-distance markers be modified as follows:

   a. Each numeral face plate of a given marker be rotated to provide a 60-degree angular orientation with respect to the runway centerline for the side being viewed.

   b. Marker rigidity be increased to withstand a minimum wind velocity of 100 knots.

   c. Provide oval style numerals instead of block style.

   d. Construct the numeral face plates of a material having a surface of low reflectance.

   e. Use a dark colored marker structure to provide maximum contrast with the white numeral.

2. The suitability of the combination of lighted runway-distance markers and painted numerals for providing distance-to-go information for civil aircraft operations be confirmed by an in-service test. The combination to be tested should include the modified markers located approximately 50 feet from the runway edge in the touchdown zones from each approach end of the runway (the first 3000 feet from threshold), with painted numerals of the United Kingdom type, applied to the central portion of the runway between the two 3000-foot touchdown zones.

3. Visual aids for providing distance-to-go information in all-weather operations be improved by the development of lighted numerals or symbols for use in the runway in proximity to the runway centerline.

ACKNOWLEDGMENTS

The Project Manager acknowledges the contribution made to this project by personnel of the 1611 Air Transport Wing, McGuire AFB, New Jersey. The operation of large jet transports in the project provided important information. The assistance of Dr. R. K. McKelvey, Human Factors Research Branch, in developing the test program and analyzing test results, Mr. C. B. Phillips, Experimentation Division, Systems research and Development Service, in conducting photometric measurements, and Mr. D. M. Millar, also of Experimentation Division, in conducting the special jet engine ingestion test, contributed greatly to the success of the project.

Ken Johnson, who piloted the light aircraft (A-1) in the distance marker collision tests, and Bernie Blum, who rode behind Ken to gather photographic test data, deserve a special note of appreciation for their contributions.

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